TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 854

DESIGN OF TOOLS FOR PRESS-COUNTERSINKING OR DIMPLING 0.040-INCH-THICK 24S-T SHEET

By R. L. Templin and J. W. Fogwell
Aluminum Company of America

Washington
August 1942

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE NO. 854

DESIGN OF TOOLS FOR PRESS-COUNTERSINKING OR DIMPLING 0.040-INCH-THICK 24S-T SHEET

By R. L. Templin and J. W. Fogwell

SUMMARY

A set of dimpling tools was designed for 0.040-inch 24S-T sheet and flush-type rivets 1/8 inch in diameter with 100° countersunk heads. The dimples produced under different conditions of pressure, sheet thickness, and drill diameter are presented as cross-sectional photographs magnified 20 times. The most satisfactory values for the dimpling tools were found to be: maximum punch diameter 0.231 inch; maximum die diameter, 0.223 inch; maximum mandrel diameter, 0.128 inch; dimple angle, 100°; punch springback angle, $1\ 1/2^\circ$; and die springback angle, 2°.

INTRODUCTION

Press-countersinking or dimpling thin sheets provides a means of obtaining flush-riveted joints that are more efficient than machine-countersunk joints. In the preparation of specimens for an investigation of dimple-riveted joints, difficulty was encountered in forming dimples which would not warp the sheet and which would properly nest together. Also the edges of the holes were not worked in the dimpling operation but were left with sharp corners to bear on the rivets. This feature was considered objectionable in that the sharp corners would probably lower the fatigue strength of the rivets. Before the investigation of dimple-riveted joints was carried on therefore, it was decided to design tools for press-countersinking or dimpling that would overcome the difficulties.

The object of this investigation was to produce a set of dimpling tools that would (1) form the required size and shape of dimples in 0.040-inch-thick 24S-T sheet to accommodate flush-type rivets with 100° counter-

sunk heads; (2) leave the sheet flat around the dimple after the dimpling operation; (3) form dimples that would fit or "nest" into each other, leaving no looseness in the joint and no gap between the sheets around the dimples; and (4) form a cylindrically shaped hole so that no sharp corners would bear on the rivet shank.

PROCEDURE AND RESULTS

In order to meet the stated requirements a set of dimpling tools was designed as shown in figure 1. These tools were designed for 0.040-inch-thick 24S-T sheet and 1/8-inch-diameter flush-type rivets with 100° countersunk heads. (Western Aircraft Standards drawing revised Dec. 8, 1939. Classification: rivet - 100° countersunk head; standard - WS-1.) These tools were designed for a single-action press, but with special adapters were used in a 20,000-pound-capacity Amsler testing machine at Aluminum Research Laboratories for this investigation.

A dimple angle of 98° was selected for the tools to allow for springback in the walls of the dimple so that when the load was released the dimple would spring back to a 100° included angle. Tests with this set of tools indicated, however, that the angle of the dimple was about the same as the dimple angle of the punch and die. These tests also indicated that the angle was reduced about 2° when the rivet was driven because of the upsetting action of the shank of the rivet.

The flange of the tools around the dimple instead of being made plane was made slightly conical to keep the sheet flat after the dimples were formed. The angle that this surface made with a plane perpendicular to the axis of the tool is labeled "punch springback angle" for the punch and "die springback angle" for the die part of the dimpling tools. (See fig. 1.) These angles were intended to overform the sheet to such an extent that when the load was released the sheet would spring back to its original flat position.

The punch springback angle was made 2° and the die springback angle was made 3° for the first tests, which indicated that the allowance for springback was too great

because the sheet was so overformed that it did not come back to its original straight position. For this reason the punch springback angle was reduced from 2° to 1 1/2° for the next tests. These tests indicated that the sheet was not overformed around the dimple but came back to a slightly bowed position. The direction of the bow indicated that the allowance for springback was not quite great enough. The die springback angle was next changed from 3° to 2° and the punch springback angle left at 1 1/2°. Tests with these tools indicated that the sheet was only slightly overformed.

In order that the hole through the sheet would be more nearly cylindrical after the dimpling operation and no sharp edges would bear on the rivet shank, the punch part of the dimpling tool was provided with a mandrel around which the sheet could be forged in the dimpling operation. This mandrel was 0.128 inch in diameter at the base and had a 2° taper on the side.

Figure 2 shows a sectioned dimple-riveted joint that was formed from sheets drilled with an 0.1285-inch-diameter (No. 30) drill, which was the same diameter as the mandrel of the punch. This photograph shows that the hole was not cylindrical after the dimpling operation and that relatively sharp corners were left to bear on the rivet shank. These results indicated that the amount of metal provided to form the dimples was insufficient to be forged around the mandrel.

In order to overcome this condition, it was necessary to allow for more metal in the dimple by reducing the size of the drilled hole. Figure 3 shows a dimple-riveted joint made the same as the one in figure 2 except that the holes were drilled with an 0.1130-inch-diameter (No. 33) drill, which was about 12 percent smaller than the diameter of the mandrel. Figure 4 shows a similar joint made the same as the other two except that the holes were drilled with an 0.1100-inch-diameter (No. 35) drill. This drill was about 15 percent smaller than the mandrel. These photographs show that more than half the length of the holes was nearly cylindrical and that there were no sharp corners bearing on the rivet shank. A slight improvement can be noted in the bearing surfaces of the dimple of figure 4 over the dimple of figure 3.

Figure 5 shows a sectioned dimple-riveted joint that was formed from sheets drilled with an 0.1065-inch diameter

(No. 36) drill, which was about 17 percent smaller than the mandrel of the punch. This photograph shows that the cylindrical portion of the hole bearing on the rivet is definitely longer than in any of the previous examples. A defect in the dimples of this joint that does not show in the photograph is a series of radial cracks around the edges of the holes. Removing the bur from the edges of the holes with fine emery cloth did not prevent or minimize the tendency for radial cracking. Cracks of this nature did not show up in the dimples formed from sheets drilled with the No. 35, 33, and 30 drills.

From these tests the smaller holes appeared to give the best bearing surfaces for the rivets; but, because of the tendency for radial cracks to form at the edges of the holes during the dimpling operation, the holes drilled with an 0.1100-inch-diameter (No. 35) drill are as small as could be used without radial cracks forming.

From the geometry of the dimple, the thickness of the wall of the dimple must be equal to the original thickness of the sheet multiplied by the sine of one-half the dimple angle in order that the dimples will fit together or nest properly. For a 100° dimple angle the thickness of the wall of the dimple would be 0.766 times the thickness of the sheet and, for a sheet thickness of 0.040 inch, the thickness of the wall of the dimple would be 0.766 x 0.040 = 0.031 inch. Sufficient pressure must be applied to forge the sheet to the proper thickness to obtain this reduction in thickness in the dimple. Pressures of 4000, 5000, and 6000 pounds were used in forming the dimples in the sheet. These pressures were tried when the punch springback angle was 1 1/2° and the die springback angle was 2°. The dimples formed with the 4000-pound pressure were not satisfactory because the walls of the dimples were not forged thin enough to make the dimples nest properly. The dimples formed with the 5000-pound pressure were more nearly the desired dimensions. The walls of the dimples were forged to the proper thickness so that the dimples nested and the sheet was left almost flat after the dimpling operation. The dimples formed with the 6000-pound pressure showed practically no improvement over those formed with the 5000-pound pressure, but the bow left in the sheet after the dimpling operation indicated that the sheet was overformed.

In order that the dimples will nest properly, the maximum diameter of the dimple must be the same as the

maximum diameter of the projecting part of the mating dimple. If the maximum diameter of the dimple is less than the maximum diameter of the projecting part of the mating dimple, the dimple will not nest and the sheets will be held apart; whereas, if the maximum diameter of the dimple is greater than the projecting part of the mating dimple, the dimple will make a loose fit and cause more of the shearing force to be carried by the rivet and less to be carried by the dimple.

The parts of the dimpling tools marked "maximum punch diameter" and "maximum die diameter" in figure 1 were both made 0.231 inch in diameter at the time the die springback angle was changed from 3° to 2°. Dimples made with the tools after this change are shown in figure 6 which shows that the maximum diameter of the dimple is less than the maximum diameter of the projecting part of the mating dimple. This difference in diameter results in the sheets being held apart by the dimple. In order to overcome this condition, the maximum die diameter was reduced from 0.231 to 0.223 inch, a reduction of 3.5 percent. Dimples made after this change are shown in figure 7. This photograph shows that the dimples fit together very well throughout.

These tools were tried on a thinner gage 24S-T sheet, 0.032 inch thick, to determine if any changes would have to be made in the dimpling for the thinner gages. Figure 8 shows a set of dimples made after the last adjustment of the tools. This photograph shows a satisfactory dimple joint, but the sheet was considerably bowed by a series of dimples. This bow indicated that the sheet was overformed by the tools and that the springback angle should be decreased for 0.032-inch thick 24S-T sheet. Otherwise the tools are apparently satisfactory for thinner gage material. An 0.1100-inch-diameter (No. 35) drill was used to drill the holes in the sheets for these dimples.

Early in the investigation both Gredag No. 83 and mutton tallow were used for lubricants to determine which was more satisfactory for lubricating the surfaces of the dimpling tools. When the only variable in the dimpling operation was the lubricant, the tests indicated that a slightly better fit was obtained in the dimples where mutton tallow was used as a lubricant.

CONCLUSIONS

From this investigation with dimpling tools designed for 0.040-inch 24S-T sheet dimpled to receive 1/8-inch-diameter flush-type rivets with 100° countersunk heads of the type known as Western Aircraft Standard WS-1 the following conclusions seem warranted:

1. The most satisfactory values of the controlling dimensions for the dimpling tools are as follows:

Maximum punch diameter, inch	0.231
Maximum die diameter, inch . (96.5 percent max. punch diam.)	.223
Maximum mandrel diameter, inch	.128
Dimple angle, degrees	100
Punch springback angle, degrees . . .	1 1/2
Die springback angle, degrees	2

2. The result of decreasing the hole size in the sheet was to increase the length of the parallel section of the hole after the dimpling operation.

3. The minimum satisfactory hole diameter in the sheet was found to be 15 percent smaller than the diameter of the mandrel of the punch, which corresponds to a diameter of 0.1100 inch. When smaller holes were used, radial cracks formed at the edge of the hole.

4. A pressure of 5000 pounds was found to be the minimum pressure that would produce a satisfactory dimple, while a pressure of 6000 pounds overformed the sheet to some extent.

5. Tools dimensioned as indicated for 0.040-inch-thick sheet also produced a satisfactory dimple in 0.032-inch-thick sheet, but the allowance for springback was too great and caused the sheet to be overformed. Additional tests would be needed to determine the correct springback angle for thinner sheets and other rivet sizes or shapes.

6. Mutton tallow seemed to be a slightly better lubricant for lubricating the tools than Gredag No. 83.

Aluminum Research Laboratories,
Aluminum Company of America,
New Kensington, Pa., January 22, 1942.

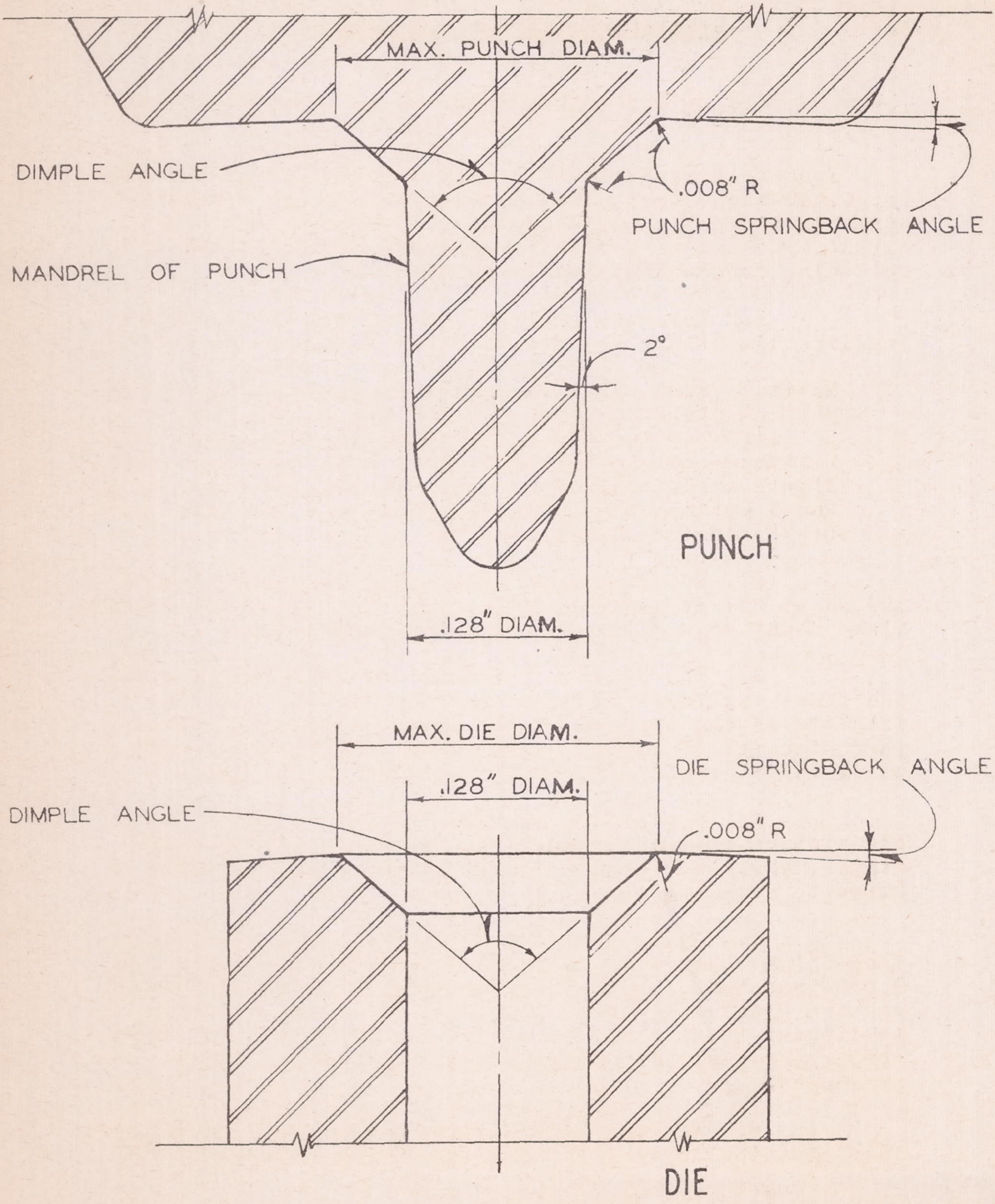

FIGURE 1.- DIMPLING TOOLS.

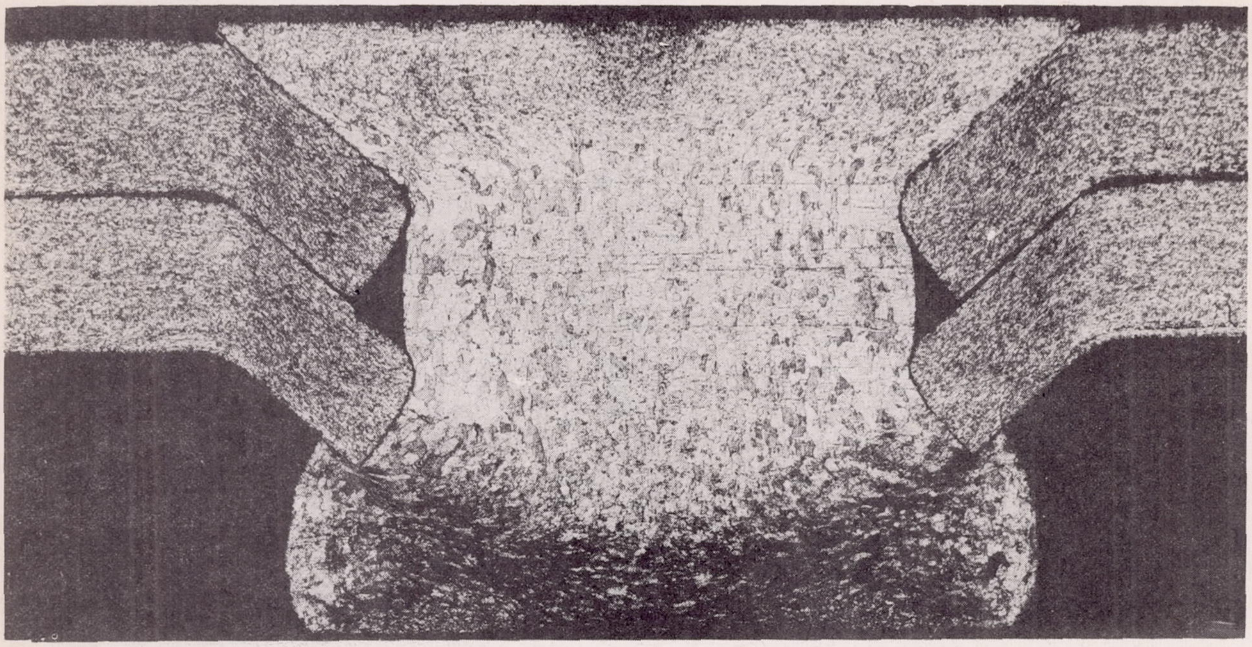

Figure 2.- Set of dimples produced with 5000-pound pressure in 0.040-inch 24S-T sheet drilled with an 0.1285-inch diameter No. 30 drill. Magnified 20 times.

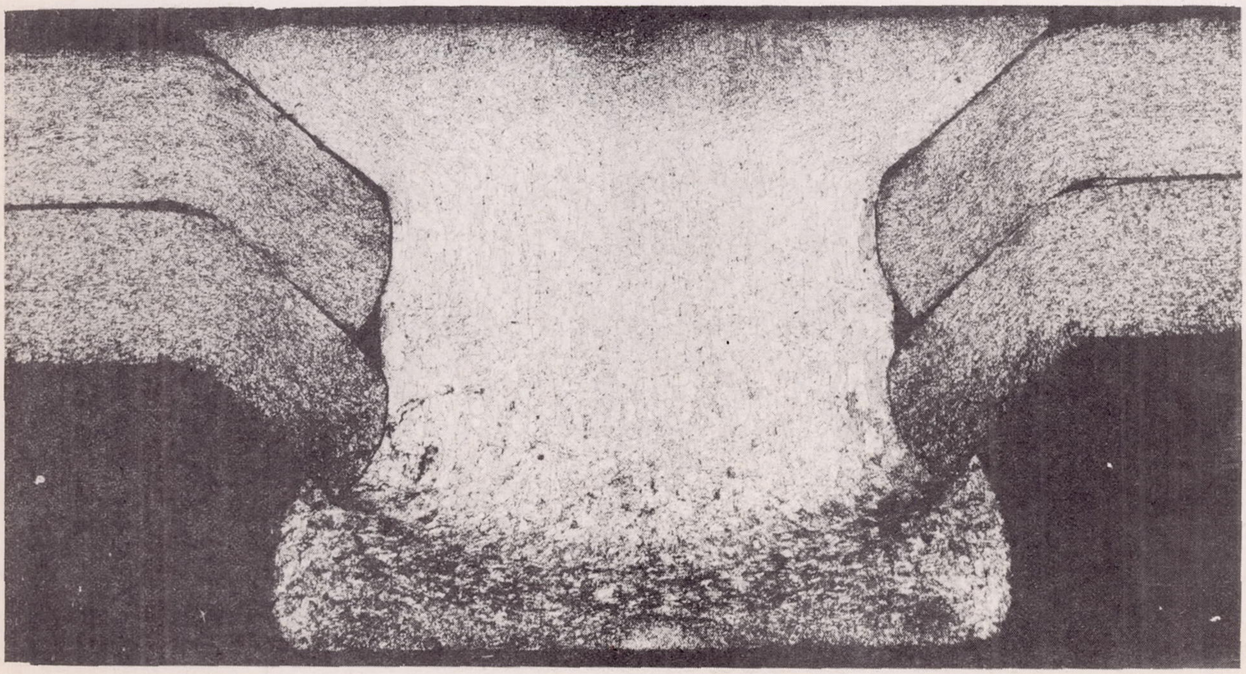

Figure 3.- Set of dimples produced with 5000-pound pressure in 0.040-inch 24S-T sheet drilled with an 0.1130-inch diameter No. 33 drill. Magnified 20 times.

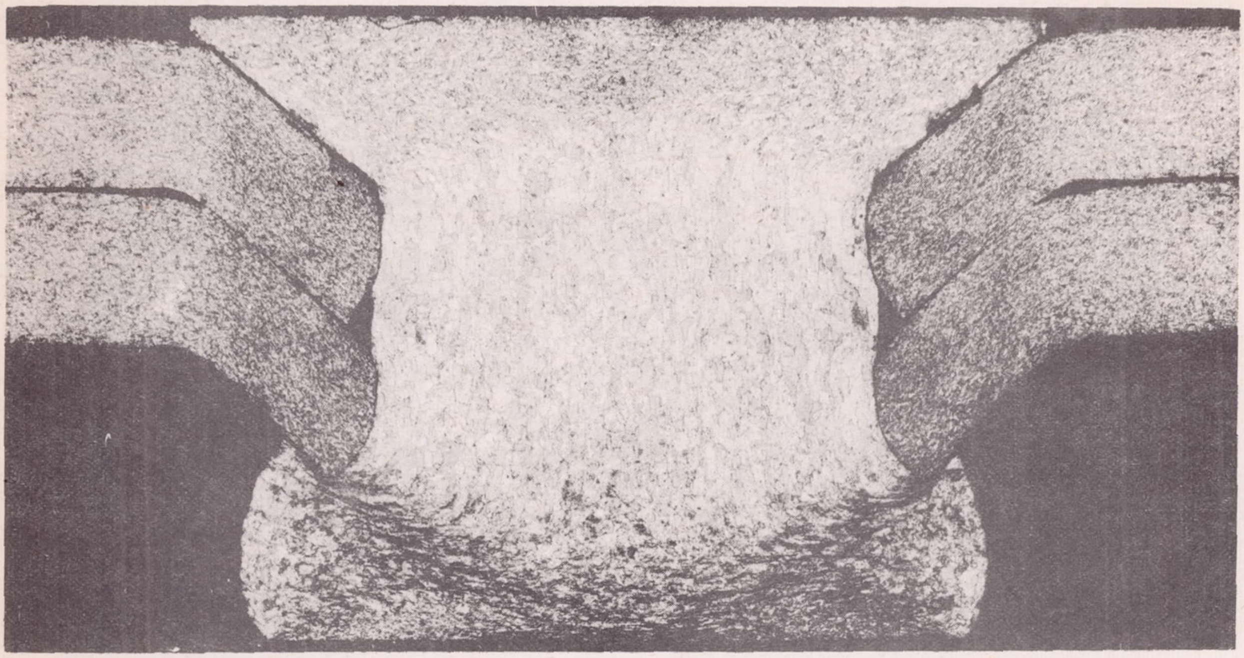

Figure 4.- Set of dimples produced with 5000-pound pressure in 0.040-inch 24S-T sheet drilled with an 0.1100-inch diameter No. 35 drill. Magnified 20 times.

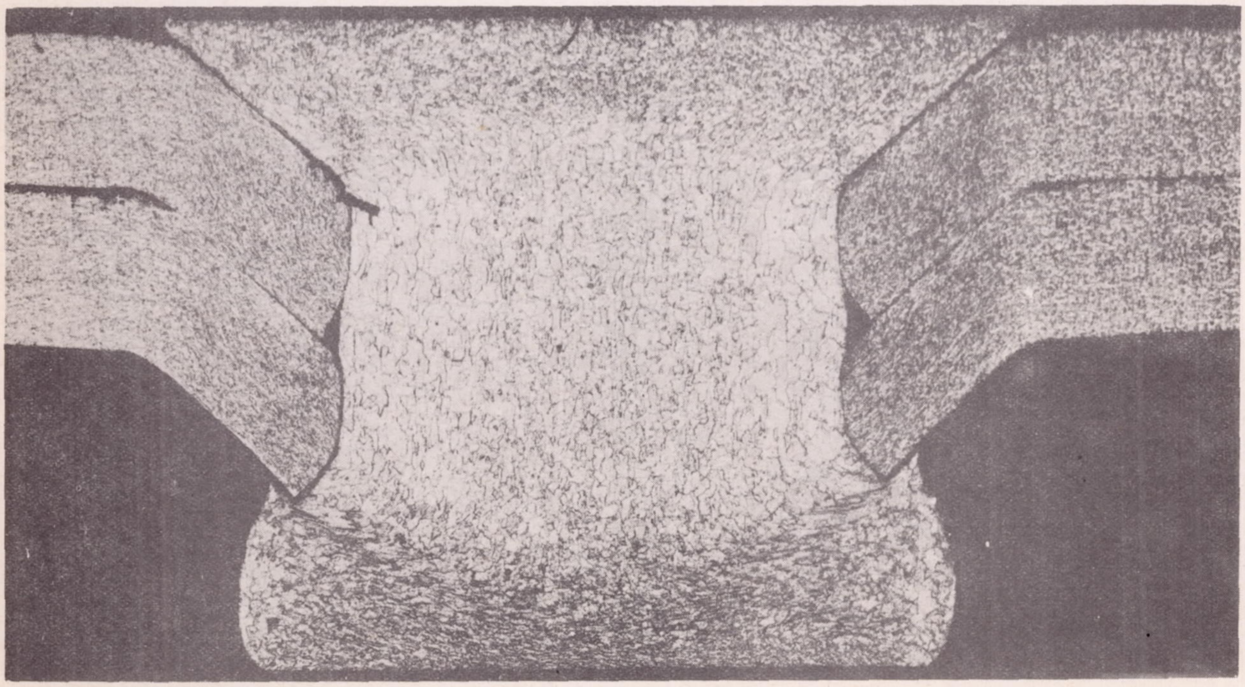

Figure 5.- Set of dimples produced with 5000-pound pressure in 0.040-inch 24S-T sheet drilled with an 0.1065-inch diameter No. 36 drill. This photograph does not show radial cracks that formed at edge of hole. Magnified 20 times.

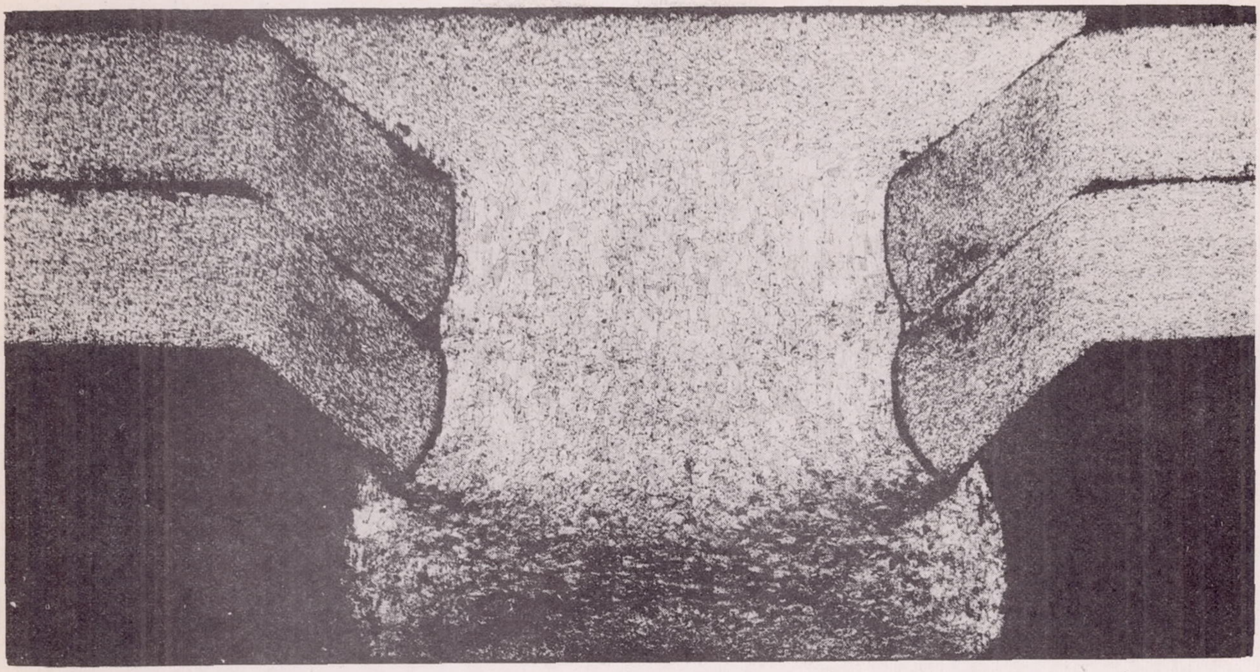

Figure 6.- Set of dimples produced in 0.040-inch 24S-T sheet when maximum punch diameter and maximum die diameter were both 0.231 inch. Dimples produced with 5000-pound pressure in sheet drilled with an 0.1100-inch diameter No. 35 drill. Magnified 20 times.

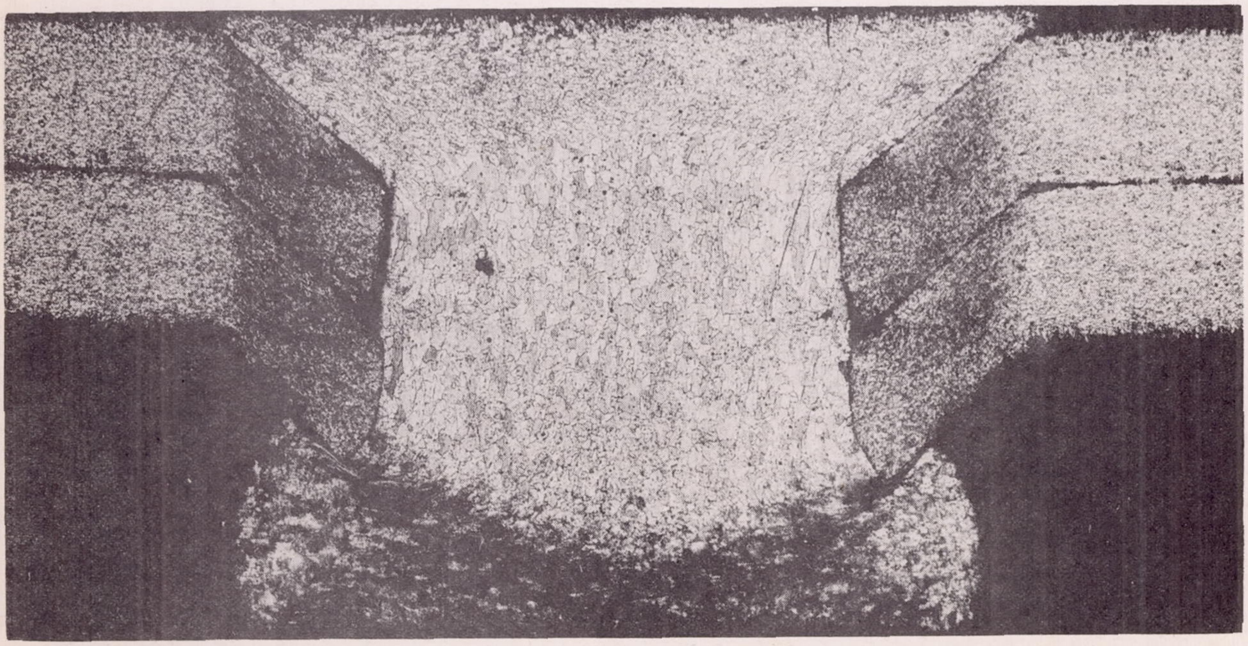

Figure 7.- Set of dimples produced in 0.040-inch 24S-T sheet after maximum die diameter was made 3.5 percent less than the maximum punch diameter. Dimples produced with 5000-pound pressure in sheet drilled with an 0.1100-inch diameter No. 35 drill. Magnified 20 times.

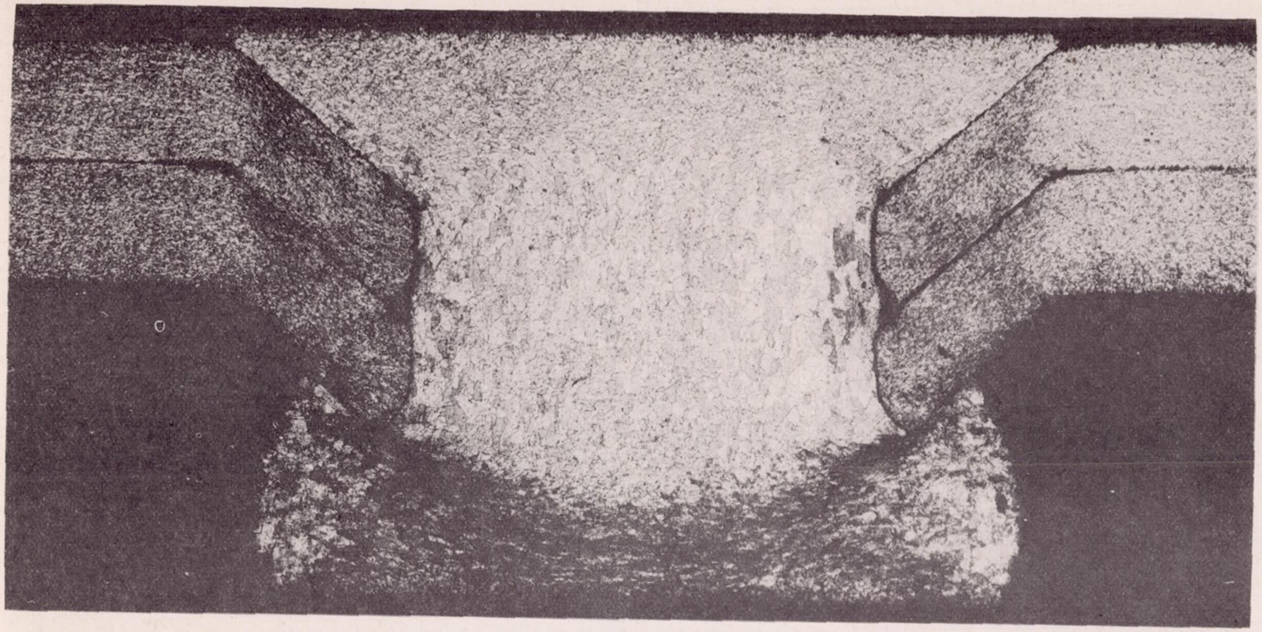

Figure 8.- Set of dimples produced in 0.032-inch 24S-T sheet with maximum die diameter 3.5 percent less than the maximum punch diameter. Dimples produced with 5000-pound pressure in sheet drilled with an 0.1100-inch diameter No. 35 drill. Magnified 20 times.